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Does the Position of Cage Affect the Clinical Outcome of Lateral Interbody Fusion in Lumbar Spinal Stenosis?

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Abstract

Study Design: A retrospective study.

Objective: This study aims to identify the ideal cage position in lateral lumbar interbody fusion (LLIF) and to investigate if the posterior instrumentation would affect the indirect decompression.

Methods: Patients underwent 2-stage surgeries: stage I was LLIF and stage II was percutaneous pedicle screws fixation after 1 week. Anterior disc height (ADH), posterior disc height (PDH), left and right foraminal height (FH), and segmental angle (SA) were measured on lateral computed tomography reconstructions. The cross-sectional area of the thecal sac (CSA) was determined by the outlined area of the thecal sac on a T2-weighted axial magnetic resonance imaging. The patients were subgroups according to the cage position: the anterior (cage located at the anterior 1/3 of disc space) and posterior groups (cage located at the posterior 2/3 of disc space). *P* values <.05 were considered significant.

Results: This study included 46 patients and 71 surgical levels. After stage I LLIF, significant increase in ADH, PDH, bilateral FH was found in both 2 subgroups, as well as the CSA (all *P*s < .01). SA increased $2.84^\circ \pm 3.2^\circ$ in the anterior group after stage I LLIF and increased $0.81^\circ \pm 3.1^\circ$ in the posterior group ($P = .013$). After stage II surgery, SA was similar between the anterior and posterior groups ($P = .20$).

Conclusion: The anteriorly placed cage may provide better improvement of anterior disc height and segmental angle after stand-alone LLIF surgery. After the second stage posterior instrumentation, the cage position would not affect the segmental angle or foraminal height.

Keywords

lateral lumbar interbody fusion (LLIF), cage position, indirect decompression, foraminal height, segmental angle, disc height

Compared with the conventional posterior decompression and instrumentation technique, lateral lumbar interbody fusion (LLIF) has been reported with advantages of less blood loss, less complication, quicker return to work.[1,2] As the population continues to age, many elder patients cannot endure more invasive posterior approach, and thus LLIF is an alternative option.

LLIF decompresses the neural elements indirectly by increasing disc height, instead of resecting disc and bony structure, which lead to stenosis. The increase of the height of foraminal area (FA) and of the cross-sectional area (CSA) of the thecal sac will lead to indirect decompression of the nerve roots and dural sac, which has been reported by previous studies.[3,4]

When performing LLIF, the position of interbody cage is quite vital for the outcome of decompression, fusion rate as well as the subsidence rate. The anteriorly located cage can

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benefit restoration of the segmental angle (SA), whereas the posteriorly located cage might be favorable for achieving the indirect decompression outcome.[5] Thus, it is somehow controversial for the position of the cage in the LLIF surgery. Park et al[4] reported that the cage within the anterior 1/3 of disc space could benefit achieving the restoration of the SA without compromising the indirect neural decompression. While Jin et al[6] found that the middle 1/3 of the disc space was better for improvement of FA and posterior disc height in LLIF. Both studies performed posterior instrumentation followed the LLIF study, which would affect the evaluation of actual surgical outcome of LLIF. On the contrary, Alimi et al[5] found that the position of cage showed no impact on the FA and the CSA. Thus, this study aims to identify the ideal cage position in LLIF and to investigate if the posterior instrumentation would affect the indirect decompression.

Material and Methods

Cohort

This is a retrospective study. The patients who underwent LLIF from June 2016 to April 2018 were reviewed. The inclusion criteria for this study were the following: (1) degenerative lumbar stenosis patients, (2) failed conservative treatment after at least 6 months, (3) presented with low back pain and claudication, (4) underwent LLIF and posterior instrumentation surgery, and (5) at least 6 months follow-up. Patients with cage subsidence during follow-up, with grade 2 spondylolisthesis or more severe, with fusion of the facets, with severe osteoporosis were excluded. Thus, the final study cohort included 46 patients with 71 levels.

Surgical Procedure

The 2-stage surgeries were performed through mini-open lateral transpsoas approach. The stage I was LLIF. The starting point was determined by the identification of the anterior margin of the disk space by feeling and aimed at the 1/3 point of the disk space. After making the starting hole in the disk space, fluoroscopy was used again throughout all surgical procedures. Cages were filled with an allogenous chip bone graft. Bone morphogenic protein was not used in all cases because bone morphogenic protein has not been approved in our country. After the completion of the anterior procedure, stage II posterior instrumentation was performed for all patients using percutaneous pedicle screws after 1 week.

Radiographic Measurements

Computed tomography (CT) scans, magnetic resonance imaging (MRI), and plain X-ray films were taken at baseline, immediate post-LLIF surgery, and immediate after posterior instrumentation. All measurements were performed on the PACS (picture archiving and communication system). Anterior disc height (ADH), posterior disc height (PDH), left and right foraminal height (FH), and segmental angle (SA) were measured on lateral CT reconstructions. ADH was defined as the perpendicular distance from the anterior corner of the lower endplate to the upper endplate. PDH was defined as the perpendicular distance from the posterior corner of the upper endplate to the lower endplate. SA was defined as the Cobb's angle between the upper endplate and lower endplate at the operated level. To determine the cage position, the upper endplate of the caudal vertebra was evenly divided into 3 zones on a lateral plain radiograph. The cage position was determined by the location of cage's center. The CSA were measured using magnetic resonance imaging (MRI). CSA was determined by the outlined area of the thecal sac on a T2-weighted axial MRI.

Table 1. Surgical Levels for the Anterior and Posterior Subgroups.

	Anterior group	Posterior group	*P*
Cage height (mm)	13.25 ± 1.3	13.11 ± 1.2	.26
Surgical levels			
L2/3	4	11	.71
L3/4	9	17	
L4/5	11	19	
Total	24	47	

Statistics

The patients were subgroups according to the cage position: the anterior (cage located at the anterior 1/3 of disc space) and posterior groups (cage located at the posterior 2/3 of disc space). Paired *t* tests were used to compare radiographic parameters between the two subgroups. Analysis of variance (ANOVA) was performed to compare the parameters between baseline, post–stage I and post–stage II surgery. Regression analysis was also performed. Statistical analysis was performed using SPSS software (version 20.0.0; SPSS Inc). *P* values <.05 were considered significant.

Results

This study included 46 patients (20 male and 26 female). Age averaged 61.45 ± 6.35 years (range: 50-78 years). A total of 71 levels of LLIF was performed: 26 single-level, 15 double-level, and 5 triple-levels fusions. Among the surgical levels, there were 15 levels at L2/3, 26 at L3/4, and 30 at L4/5. The height of cages was 12 mm for 33 levels, 14 mm for 35 levels, and 16 mm for 3 levels. The width of the cages averaged 47.4 ± 3.4 mm (range, 45.0-55.0 mm). The comparison was performed between levels. The anterior cage group has 24 levels and the posterior group has 47 levels (Table 1). The average height of the cages was 13.25 ± 1.3 mm in the anterior group and 13.11 ± 1.2 mm in the posterior group ($P = .26$). At baseline, no significant difference was found between anterior and posterior groups in terms of ADH, PDH, and FH (all *P*s > .05, Table 2).

As shown in Table 2, after stage I LLIF, significant increase in ADH, PDH, bilateral FH was found in both 2 subgroups, as

Table 2. Comparison of Radiographic Parameters Between Anterior and Posterior Subgroups.

	Anterior group	Posterior group	*P*
ADH (mm)			
Baseline	13.41 ± 4.02	14.13 ± 3.25	.33
Post–stage I LLIF	16.82 ± 3.12	15.05 ± 2.97	.03
Post–stage II fixation	17.05 ± 3.22	15.62 ± 3.04	.25
P between baseline and post–stage I	<0.001	0.005	—
P between post–stage I and post–stage II	.53	.61	
PDH (mm)			
Baseline	8.65 ± 2.74	7.43 ± 2.62	.68
Post-LLIF	9.83 ± 1.77	9.27 ± 2.11	.54
Post–stage II fixation	9.92 ± 1.85	9.31 ± 2.42	.33
P between baseline and post–stage I	<.001	<.001	—
P between post–stage I and post–stage II	.42	.68	
SA (deg)			
Baseline	8.24 ± 4.28	8.41 ± 5.33	.65
Post-LLIF	11.08 ± 3.87	9.22 ± 4.38	.04
Post stage II fixation	10.23 ± 3.65	9.35 ± 4.18	.20
P between baseline and post–stage I	<.001	<.001	—
P between post–stage-I and post–stage II	.74	.56	
Left FH (mm)			
Baseline	18.31 ± 2.45	17.84 ± 2.62	.84
Post-LLIF	19.64 ± 1.46	19.11 ± 1.74	.72
Post–stage II fixation	19.52 ± 1.33	19.27 ± 1.69	.76
P between baseline and post–stage I	.002	.001	—
P between post–stage I and post–stage II	.75	.47	
Right FH (mm)			
Baseline	17.85 ± 2.66	16.96 ± 2.48	.59
Post-LLIF	19.03 ± 1.84	18.72 ± 1.49	.47
Post–stage II fixation	18.84 ± 1.62	18.92 ± 1.33	.68
P between baseline and post–stage I	.002	.002	—
P between post–stage I and post–stage II	.24	.55	
CSA (mm^2)			
Baseline	92.56 ± 49.89	83.68 ± 57.66	.18
Post-LLIF	124.82 ± 47.36	116.39 ± 52.44	.31
P between baseline and post–stage I	<.001	<.001	—

Abbreviations: LLIF, lateral lumbar interbody fusion; ADH, anterior disc height; PDH, posterior disc height; FH, foraminal height; SA, segmental angle; CSA, cross-sectional area of the thecal sac.

well as the CSA (all *P*s < .01). Comparing with posterior group, the increase of ADH was significantly larger in anterior group (3.41 ± 3.25 mm vs 1.92 ± 3.05 mm, $P = .022$), while the increase of PDH was similar between the 2 subgroups ($P = .66$). SA increased 2.84° ± 3.2° in anterior group after stage I LLIF and increased 0.81° ± 3.1° in posterior group ($P = .013$), and SA was significantly larger in anterior group ($P = .04$). The increase of bilateral FH and the CSA showed no difference between the 2 groups ($P > .05$, Table 2).

After stage II posterior instrumentation, ADH, PDH, and bilateral FH showed no significant change compared to those after stage I LLIF surgery. Slightly increased SA was found in the posterior group while SA showed no statistically significant change in both groups (Table 2). After stage II surgery, SA was similar between anterior and posterior group ($P = .20$). CSA was not calculated after posterior instrumentation due to metal artifacts.

Table 3. Multivariate Regression for Increase of CSA.

Parameters	β ± SE	*P*
Cage position	−0.14	.42
Change of SA	0.07	.38
Surgical levels	—	—
Change of ADH	—	—
Change of PDH	—	—

Abbreviations: ADH, anterior disc height; PDH, posterior disc height; SA, segmental angle; CSA, cross-sectional area of the thecal sac.

To identify the factors affecting the increase in CSA, multivariate regression analysis was performed (Table 3). The multivariate regression analyses (stepwise) were performed to compare the relative contributions of each of the parameters on increase in CSA. The parameters used for the regression analysis included cage position, change of SA, surgical levels, change of ADH and change of PDH. Multivariate analysis revealed no significant factors that affect the increase in CSA.

Discussion

LLIF is a surgical technique that achieves indirect decompression and restoration of lumbar alignment with the insertion of a large interbody cage into the intervertebral space, which distracts the annular fibrous and ligaments.[7] The main aim of LLIF surgery is to restore disc space height which would lead to reduction of pain and improvement in disability. The minimally invasive LLIF approach has been reported to reduce tissue trauma, operative time, and recovery time.[2] The effects of successful indirect decompression on the neural element have been reported in a number of studies.[8,9] It also has been reported that the SA increased by a mean of 2.8° to 9.0° per level through LLIF.[4] However, the indirect decompression and increase of SA may not be able to be achieved at the same time since more increase of SA may lead to smaller PDH. Therefore, this study analyzed the impact of cage position on decompression and change of SA. The results revealed that the cage position within the anterior 1/3 of disc space would benefit the anterior disc height as well as SA after LLIF surgery, but the better SA in the anterior group after stage I surgery is lost after additional posterior instrumentation.

The benefit of LLIF on SA has been reported in many studies. Park et al[4] reported greater increase in ADH and SA when the cage was placed in the anterior 1/3 area than in the middle 1/3 area. Kepler et al[10] also demonstrated that anterior cage position resulted in the largest SA increase (7.4°) whereas posterior position reduced the angle by a mean of −1.2°. Their study was conducted based on patients with both LLIF and posterior fixation. Our results showed larger ADH and SA in anterior group after stage I LLIF surgery, while SA showed no difference after stage II posterior instrumentation. The difference of SA after stage I and stage II surgery may be due to the pressure during posterior instrumentation. When performing percutaneous pedicle screw fixation, the rod was precontoured, surgeons would choose different rods based on the requirement of lumbar lordosis restoration and press to install the rod. The different precontoured rods may lead to different change of SA in anterior and posterior group. In addition, since the disc had been removed and the facets was not fused according to inclusion criteria, the pressure from posterior side would increase SA, especially in posterior group where the cage (like a hinge) was closer to posterior edge of vertebra. Our results also observed slightly decreased PDH after stage II fixation even if the difference was not statistically significant. Melikian et al[11] showed in a biomechanical study that none of the cages, including the 30° lordotic cage, caused a decrease in PDH suggesting hyperlordotic cages do not cause foraminal stenosis.

The sagittal alignment has been emphasized in spinal degenerative deformity and degenerative diseases in the recent decades.[12] The restoration of lumbar lordosis was correlated to better clinical outcome and less incidence of adjacent segmental degeneration (ASD), even in short-level fusion surgery. Kim et al[13] reported that the restoration of the SA is important to increase pelvic tilt and to achieve good clinical outcomes in L4-L5 degenerative spondylolisthesis. Recently, Tian et al[14] showed that improved lumbar lordosis was correlated to a lower incidence of ASD, and that proper disc height and segmental lordosis restoration were essential for prevention of ASD. According to our results, both anteriorly and posteriorly placed cage could be used to improvement SA after LLIF surgery.

Regarding to indirect decompression, significant increase in CSA and bilateral FH were observed in this study after LLIF. Our results of CSA and FH change was comparable to previous reports. Rao et al[15] reported that anterior lumbar interbody fusion resulted in significant indirect foraminal decompression and that PDH was a significant factor in the restoration of the FH. Oliveira et al[16] showed an increase of average disc height (41.9%), FH (13.5%), foraminal area (24.7%), and central canal diameter (33.1%) after LLIF surgery. However, our study failed to find the independent factors for CSA increase based on regression analysis. Park et al[4] demonstrated that preoperative CSA was the only independent factor which correlated to the increase of CSA and that the cage position did not affect the increase of CSA. Thus, the cage position and the cage size would not affect the indirect decompression in a LLIF surgery.

Based on our results, we may postulate that the placement of cage may depend on different situations. In patients with lumbar hypolordosis or even kyphosis, old age, osteoporosis and in those who may have endplate injury during surgery, we recommend placing the cage in the anterior 1/3 of disc space to avoid potential cage subsidence and to improvement segmental lordosis. For those with severe foraminal stenosis, the cage could be placed at the posterior 2/3 of the disc space since our results showed slightly more increase of bilateral FH (without statistical significance).

Limitations of the current study include its relatively small sample size and the lack of long-term follow-up data. Longer-term data is necessary for determining pseudarthrosis rates regarding cage subsidence between anterior and posterior cage group. In addition, this study did not include the evaluation of clinical outcomes because the study time was immediate after surgery. However, it is well-documented in other reports that successful indirect neural decompression resulted in good clinical outcomes.

Conclusion

The anteriorly placed cage may provide better improvement of ADH and SA after stand-alone LLIF surgery. After the second stage posterior instrumentation, the cage position would not affect the SA or FH. The indirect decompression, presented by CSA, would not be affected by the cage position.

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Author Contributions

GQ, XW, JL, and BYue were responsible for the design, conducting the study, data analysis. MG and BYang were responsible for the writing process. All authors read and approved the final manuscript.

Ethical Approval

Written informed consent was obtained from all participants in accordance with protocol approved by the Affiliated Hospital of Qingdao University Research Ethics Board.

Declaration of Conflicting Interests

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